Transportation Asset Management Case Studies

Presented by

U.S. Department of Transportation
Federal Highway Administration

LIFE-CYCLE COST ANALYSIS

The Colorado Experience

Transportation reconstruction and expansion project on I-25 in Denver.

What is LCCA?

Life-Cycle Cost Analysis (LCCA) is an evaluation technique that supports informed investment decisions. While it builds on principles of economic analysis that have been used to evaluate highway and other public works investments for years, LCCA considers both near and long–term activities required to maintain highway assets above some minimum performance level. Specifically, when it has been decided that a project will be implement ed, LCCA will assist in determining the lowest-cost way to accomplish the project. The LCCA approach enables a cost comparison of competing design (or preservation) alternatives or system investment strategies. Differential costs that occur throughout the life of an alternative are included. LCCA does this by incorporating discounted long-term agency and user costs that occur over the life of highway, bridge, and other roadway assets to identify the best value for investment expenditures (e.g., the lowest cost that satisfies the performance objective being sought).

FRONT COVER PHOTO:
I-70 at Empire Junction.

Note From the Director

The Federal Highway Administration's Office of Asset Management is aggressively promoting a different way for transportation agencies to distribute their resources among alternative investment options. This new way of doing business, referred to as "Asset Management," is a strategic approach to maximizing the benefits resulting from the expenditure of agency resources.

For any transportation agency, the progression toward Asset Management will involve a myriad of activities. These endeavors will differ from State to State. For example, some agencies will pursue a data integration strategy in order to ensure comparable data for the evaluation of investment alternatives across asset classes. Others will move to deploy economic analysis tools to generate fact-based information for decision makers. Still others will want to integrate new inventory assessment methods into their decision making processes.

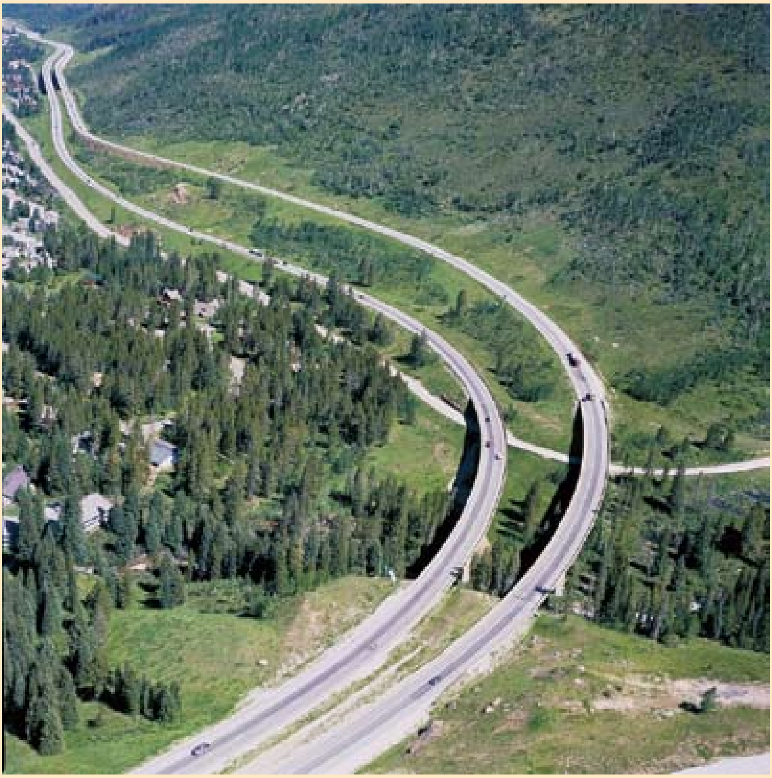
Much can be learned from those who are integrating into their organizations the tools of Asset Management. To spark the exchange of information, we have prepared a series of case studies focused on agencies that are leading the way. Four tracks of Asset Management case histories are available covering data integration, economics in Asset Management, the Highway Economic Requirements System (HERS)-State Version, and Life-Cycle Cost Analysis (LCCA). As the series progresses, we will add new State reports to each of the tracks and create new tracks addressing additional facets of Asset Management, such as change management and performance measurement.

On behalf of the Office of Asset Management, I am pleased to provide this series. We believe the case studies will help agencies meet the challenges of implementing Asset Management programs, providing vital insights into approaches for which demand grows in our economic times.

Butch Wlaschin
Director, Office of Asset Management

Note to the Reader

The Transportation Asset Management Case Study Series is the result of a partnership between State departments of transportation and the Federal Highway Administration's (FHWA's) Office of Asset Management. FHWA provides the forum from which to share information, and the individual States provide the details of their experiences. For each case study report, State transportation agency personnel were interviewed by FHWA, and the resulting material was approved by the State. As such, the case study reports rely on the agencies' own assessments of their experience. Readers should note that the reported results may or may not be reproducible in other organizations.



Aerial view of I-70 near Vail.

Executive Summary

A diverse landscape, central geographical location, and growing population are among the constant factors influencing the Colorado Department of Transportation's (CDOT's) decisions and activities. But in the last few years, economic conditions have added complexity to the State's highway program. Not only is transportation funding at an all-time low, but inflation and the rising cost of materials have reduced CDOT's buying power. In addition, the agency faces intense public scrutiny about the use of taxpayer funds.

To demonstrate its concern over the effective use of funding for Colorado's transportation system, CDOT has adopted an innovative and rational approach to investing in its roadways—Life-Cycle Cost Analysis (LCCA).

After more than 25 years of evaluating its transportation asset investment decisions, CDOT can be considered a leader in the application of LCCA to support those decisions. Since the early 1970s, the agency's pavement office has meticulously developed an LCCA process that incorporates results from statistical research, as well as knowledge from actual pavement projects, into its policies and procedures to produce a sound, long-term approach to managing assets.

CDOT's pavement engineers have continuously evolved the LCCA process by adapting innovative technologies and approaches to meet the needs of the State's transportation assets:

- In the late 1990s, CDOT began to shift away from the deterministic method toward the probabilistic method for LCCA in order to address variability in the LCCA input values.
- At the same time, the State began using an upgraded version of the Federal Highway Administration RealCost LCCA software to establish costs under both types of analyses.
- A Pavement Type Selection Committee made up of transportation authorities helps mediate pavement options if the results of the deterministic and probabilistic analyses are statistically close.
- Industry stakeholders also have the opportunity to provide input to the Committee, an element of openness that has earned respect for CDOT's process.
- The State has embraced the support of FHWA and actively participates in the federal agency's LCCA, pavement management, and other training classes.

As a result of these innovations, the pavement office receives frequent requests from other asset managers within the agency, such as the Bridge Design and Management Branch, for assistance with evaluating long-term decisions about additional highway assets.

Through the years it has deployed LCCA, CDOT has learned valuable lessons that serve Colorado, but are also applicable to other States' transportation systems. CDOT is confident that its success with Life-Cycle Cost Analysis as an investment strategy will continue to serve the State—and the transportation community—in the years ahead. ■

AGENCY FACTS

What began 100 years ago as a three-member Highway Commission with a budget of $56,000 has grown into the Colorado Department of Transportation, which now manages a multi-modal transportation system with an annual budget of $1.3 billion. Six individual transportation Regions manage 9,134 miles of State highways, 3,406 State-owned bridges, and 20 State-owned tunnels.

In FY 2008, CDOT served its broad customer base by:

- Repairing and maintaining more than 8.7 million square yards of roadway surface, using 248,018 tons of asphalt and 178,841 gallons of liquid asphalt,
- Snowplowing, sanding, and/or deicing 7.2 million miles of highway,
- Replacing and repairing 67,830 signs and sign posts,
- Triggering with explosives more than 500 avalanches to reduce risk of snow slides affecting 160 Colorado highways,
- Implementing a pavement design training program, including extensive instruction about LCCA,
- Improving Homeland Security provisions to ensure a multidisciplinary approach to emergency planning and preparedness, and
- Increasing the scope of Intelligent Transportation Systems to improve and enhance mobility and traffic safety throughout Colorado.[1]

Although Interstate highways in Colorado account for only about 10 percent of the total miles in the State system, they carry 40 percent of the State's travel.

Even with these advances, CDOT faces a diversity of challenges shared by many of its sister agencies. Among them:

- Colorado highways handle more than 28 billion vehicle-miles of travel annually.
- The State's population grew 44 percent (twice the national average) between 1990 and 2006 and now numbers nearly five million residents located in both urban hubs and remote rural communities.

[1] Colorado Department of Transportation 2008-2009 Fact Book, pp. 32-33.

- CDOT moves passengers, freight, and information on a regional, Interstate, and international level.
- The State has harsh winters and large variations in terrain, climate, and demographics.
- Fifty-nine percent of Colorado's roadways are rated in "fair" or "good" condition, based on the years of remaining service life.
- With a 20-year design life, the Interstate system—75 percent of which was built before 1970—now requires extensive repairs.
- Motor fuel taxes that the State currently collects are inadequate to meet mobility needs. As a result, CDOT is facing a severe funding shortfall and is considering options to increase revenue, such as raising certain truck fees and tolling existing roads. [2]

All of these factors contribute to the constant—and increasing—need to more effectively evaluate and implement new projects and maintenance programs.

Snow plowing on I-25 at Colorado Boulevard in Denver.

[2] Colorado Department of Transportation 2008 Annual Report, pp. 24-29.

SETTING THE STAGE

What Did CDOT Have?

In response to a period of high inflation in the United States in the late 1970s, CDOT began using Life-Cycle Cost Analysis to support its investment decisions. In 1981, CDOT's pavement office, seeking to mitigate the effects of the economic environment, mandated that an LCCA be completed in the design phase for all major projects. These early analyses included specific input values which produced deterministic results. The objective was to implement strategies that optimized the use of available resources.

Similar economic challenges since the late 1990s prompted CDOT to account for fluctuating economic indicators, particularly in the discount rate used in its LCCA. Common practice in representing the present value of future construction costs is to account for the "opportunity cost" or "time value" of money using the real rate of return (nominal rate less inflation) of a Treasury Bill as a surrogate. To provide a better estimate of the appropriate rate to use in the LCCA and mitigate much of the uncertainty in choosing a rate, CDOT implemented an additional analysis method based on probabilistic inputs.

Aerial photo of I-70 near Gypsum.

What Did CDOT Want?

The population explosion of the past two decades and the growth in daytime traffic increased the viability of performing nighttime work on the CDOT roadway system. Justifying the increased expense of nighttime construction demanded a process to quantify the cost benefit to roadway users.

In addition, CDOT's 2008 Annual Report identified regional demands that far exceeded available resources. For instance, Region 4 identified necessary improvements that exceeded $1 billion, with $60 million needed immediately simply to maintain its roads until improvement projects could be approved and funded. Region 6 expressed concerns about competing demands for expansion and preservation in light of the projected $48 billion Statewide budget shortfall.

Despite the fact that local Metropolitan Planning Organizations (MPOs) requested more funding as well, the State's Transportation Commission recommended sustaining the existing system due to revenue constraints.

In order to operate effectively in this environment, CDOT needed a comprehensive, user-friendly process for analyzing and selecting strategies that could be implemented by the Regions and defended before the State legislature, the public, and industry leaders. LCCA met this challenge.

I-70 near Evergreen.

How Did CDOT Get There?

CDOT's LCCA Program and Method

The State Materials Engineer, recognizing a need to evaluate the life-cycle costs of pavement design options, introduced a process policy memo into CDOT's Construction Manual in the late 1970s. The process was formalized in1990 when LCCA guidelines were included in the State's Pavement Design Manual. Although use of the processes set out in the Pavement Design Manual is mandated agency-wide, each of the six individual transportation Regions performs its own pavement design, cost analyses, and justifications, autonomously, without central review.

The guidelines originally required that an LCCA be completed for new pavement construction projects exceeding $1 million in initial costs. For reconstruction, LCCAs would be required for any pavement projects exceeding five million Equivalent Single Axle Loads (ESALs). The procedures have been updated three times since their inception—in 1994, 2000, and 2007—and currently require that an LCCA be completed for projects with more than $2 million in initial pavement costs.

For the LCCA, once the pavement designs for asphalt and concrete have been completed, the initial construction, annual maintenance, required rehabilitations, and user costs are calculated for each. These costs are then run through a 40-year Life-Cycle Cost Analysis to identify the alternative with the lowest overall price tag and best value for the traveling public.

CDOT increased its analysis period to 40 years in 2002 because FHWA's LCCA Policy Statement recommended an analysis period of at least 35 years for all pavement projects. CDOT planned to follow FHWA's recommendation, as well as to account for pavement rehabilitation cycles, in order to prevent having to use a salvage value. Unmodified hot mix asphalt (HMA) has a 10-year rehab life, which easily led to a 40-year analysis period.[3]

Figure 1: CDOT Pavement Analysis Parameters lists the agency's general LCCA guidelines for various pavement types.

[3] Colorado Department of Transportation's Current Procedure for Life Cycle Cost Analysis and Discount Rate Calculations, January 2009, pp. 1-2.

Figure 1: CDOT Pavement Analysis Parameters[4]

Pavement Type	***Analysis Period*** *(in years)*	***Initial Design Period*** *(in years)*	***Default Rehabilitation Strategies***
Asphalt	40	20	• Two-inch HMA overlays at 10, 20, and 30 years; two-inch milling may be required at years 20 and 30. • Two-inch HMA with polymer modified binder mixture overlays at 11, 22, and 33 years; two-inch milling may be required at 22 and 33 years.
Portland Cement Concrete	40	30[5]	Travel Lanes Only, No Shoulders: • PCCP with dowel and tie bars will require 50 percent full width diamond grinding of ¼ inch to restore rideability at 22 years with joint resealing and ½ percent slab replacement in the travel lanes. • PCCP without dowel or tie bars will still require full width diamond grinding of ¼ inch with joint resealing and one percent slab replacement in the travel lanes.
	40	20	• Two-inch HMA overlay at 20 and 30 years or three-inch overlay at 20 and 30 years in a high volume urban area.
Restoration, Rehabilitation & Resurfacing Treatments	40	10, 20, or 30	Varies

Computational Approaches and Tools

In 1998, CDOT recommended using probabilistic in lieu of deterministic inputs for their LCCA. The types of inputs differ in the way they address the variability associated with LCCA input values.

For both types, CDOT uses FHWA RealCost Software to analyze pavement construction and rehabilitation. The software accepts

[4] Source: Colorado Department of Transportation, 2009 Pavement Design Manual.
[5] Add ¼ inch to thickness for future diamond grinding.

deterministic or probabilistic inputs from various sources and computes the present value of both agency and work zone user costs for each alternative being evaluated. In computing work zone user cost, RealCost compares traffic demand to roadway capacity on an hour-by-hour basis. This reveals the traffic conditions that will result and calculates the user costs of impacts caused by work zones.

In addition, CDOT complements RealCost with a custom developed external application called WorkZone. RealCost can compute work zone user cost internally using hourly demand-capacity considerations and user input traffic data (hourly traffic volume, vehicle mix, number and type of lane closures, work zone and normal speed limits, etc.). Alternatively, the user can input a work zone user cost for each activity as a lump sum amount calculated externally. CDOT adapted the second option by allowing a range of input variables, such as type of lane closure, work zone and standard speed limits, types of work to be completed, functional class, and percent of grade. With this information, WorkZone can calculate CDOT user costs per mile and per hour.

Deterministic Analysis

When using the deterministic approach, an analyst assigns each LCCA input variable a fixed, discrete value after determining the value most likely to occur for each parameter. Usually the determination is based on historical evidence or the judgment of a seasoned professional whose experience and training have contributed to a well-designed pavement management system. [See Figure 2: FHWA Training Related to Pavement Management.]

Collectively, the input values are used to compute a single life-cycle cost estimate for the alternative under consideration.

Figure 2: FHWA Training Related to Pavement Management

- *Analysis Of PMS Data for Engineering Applications* (NHI Course Number: 131105)
- *Data Integration Workshop*
- *Economic Analysis for Highway Decision Makers Workshop*
- *HERS-St Workshop*
- *Hot-Mix Asphalt Construction* (NHI Course Number: 131032)
- *Hot-Mix Asphalt Materials, Characteristics & Control* (NHI Course Number: 131045)
- *Hot-Mix Asphalt Production Facilities* (NHI Course Number: 131044)
- *Live/Instructor-Lead Fundamentals of Life-Cycle Cost Analysis (LCCA) Distance Learning Course*
- *FHWA RealCost Life-Cycle Cost Analysis Software Onsite Implementation Workshop*
- *Pavement Management Systems: Characteristics of an Effective Program* (NHI Course Number: 131116A)
- *Pavement Preservation Online Guide and Training* (NHI Course Number: 131110)
- *Pavement Preservation: Design and Construction of Quality Preventive Maintenance Treatments* (NHI Course Number: 131103)
- *Pavement Preservation: Integrating Pavement Preservation Practices and Pavement Management* (NHI Course Number: 131104)
- *Pavement Preservation: Optimal Timing of Pavement Preservation Treatments* (workshop) (NHI Course Number: 131114)
- *Pavement Preservation: Selection and Timing of Preventive Maintenance Treatments* (NHI Course Number: 131115)
- *Transportation Asset Management* (NHI Course Number: 131106)

The FHWA Office of Asset Management offers a range of training opportunities to enhance pavement management practices. For further information on the courses listed, go to http://www.fhwa.dot.gov/infrastructure/asstmgmt/training.cfm.

Probabilistic Analysis

Although, traditionally, applications of LCCA have relied on deterministic analysis, the approach fails to address simultaneous variation in multiple inputs and does not convey the degree of uncertainty associated with life-cycle cost estimates.

As a result, CDOT added probabilistic LCCA inputs to its process in order to account for these issues and to create a distribution curve showing costs associated with varying probabilities. With probabilistic inputs, CDOT can compute results that describe their likelihood of occurrence and simultaneously factor in differing assumptions for many variables.

CDOT uses RealCost's Monte Carlo simulation feature to randomly sample from probability distributions for each input. The agency runs the sampled input values through a present value formula to calculate a discrete output, and then repeats this process over and over again. The discrete outputs are arranged in the form of an LCCA result histogram, and a probability distribution covering all potential outcomes is developed.[6]

CDOT uses three types of distribution curves in its probabilistic LCCA process:

- A **triangular** distribution is used when evaluating initial construction costs for probabilistic LCCA. This is because historical data combined with quantity of scale provide a reasonable minimum, maximum, and average.
- A **normal** distribution is used for incorporating the discount rate into a probabilistic analysis. This is because a mean and standard deviation for the discount rate can be easily calculated from the 10-year moving average of real interest rates.
- **Lognormal** distribution is used for calculating the activity service life of initial construction and rehabilitation projects. This is because, although there is some variability, the number of years required for service life must be positive.[7]

The Discount Rate

Using the discount rate, or discounting, involves adjusting dollars for the opportunity value of time. When using the discount rate, which CDOT has currently set at 3.3 percent, future costs of projects are expressed in constant dollars and then discounted to the present rate. Using the real discount rate facilitates comparison of pavement alternatives in terms of

[6] FHWA-IF-03-032. Economic Analysis Primer, p. 31.
[7] Colorado Department of Transportation's Current Procedure for Life Cycle Cost Analysis and Discount Rate Calculations, January 2009, p. 2.

reallocation of time (moving a project a few years forward or back without altering its real value) and allows a lump sum value to be transformed into a multiyear flow. [8]

CDOT's LCCA processes include a calculation of "present value" that uses the discount rate and the time a cost was—or will be—incurred to establish the present value of the cost in the base year of the analysis period. While there is no need to consider the present value for initial costs, the determination of future costs is time dependent.

The time period used is the difference between the point at which initial costs are incurred and the time future costs are likely to occur. Initial costs are set at the beginning of the study period at year zero, the base year. The present value calculation is the equalizer that allows the summation of initial and future costs. Along with time, the discount rate also dictates the present value of future costs. Because the current discount rate is a positive value, future expenses will have a present value less than their cost at the time they are incurred. If future costs of a project are provided in nominal dollars, conversion of these nominal dollars to constant dollars can be accomplished.[9]

Due to the shift in discount rate between the 2008 and 2009 versions of the CDOT Pavement Design Manual, any project that has not yet been to Field Inspection Review (FIR) will be reassessed to determine if the current pavement choice is still the most economical. In any situation in the future, if the new 10-year average discount rate varies by more than 0.5 percent from the original, a new LCCA is to be performed.[10]

Pavement Type Selection Committee

CDOT has adopted an interesting and effective process for resolving "close calls" between possible pavement options after the LCCA on each has been performed.

If, after comparing competing alternatives, it is determined that the present value of the life-cycle costs are within 10 percent of each other,

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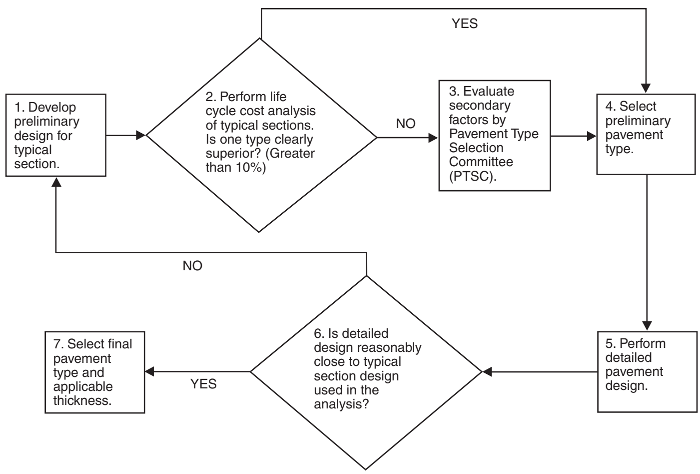
[8] Ibid. pp. 2-4.

[9] Colorado Department of Transportation. Report No. CDOT-2006-17. Life Cycle Cost Analysis and Discount Rate on Pavements for The Colorado Department of Transportation. October 2006, pp. 9.

[10] Colorado Department of Transportation, 2009 Pavement Design Manual, pp. 10-5.

the CDOT Region presents a report of its findings to a Pavement Type Selection Committee. There it is reviewed further and a recommended choice is selected for a final decision by the State's Chief Engineer. A suggested flow chart illustrating the selection process for new pavement construction is shown in Figure 3: Pavement Selection Process Flow Chart.

Figure 3: Pavement Selection Process Flow Chart



Source: Colorado Department of Transportation 2009 Pavement Design Manual

The Committee consists of nine members: the Region's Transportation Director, Program Engineer, Resident Engineer, Maintenance Superintendent, Materials Engineer, three participants from the CDOT Staff Branches—the Staff Construction Area Engineer, the Materials and Geotechnical Branch Manager, and a representative from Pavement Design—and an FHWA Pavements Engineer.

The purpose of the Committee is to:

- Ensure the pavement type decision aligns with the unique goals of the project,
- Provide industry with the opportunity to review the LCCA document,
- Ensure statewide consistency of decision-making,
- Formalize the decision process involved in the Region's pavement type selection,
- Create accountability for the decision at the level of Chief Engineer, and
- Improve the credibility of the decision by following a documented process and clearly communicating the reasons for the choice.[11]

While the Chief Engineer makes the final decision on pavement type, the involvement of Committee members helps ensure an independent review of the initial LCCA. Committee members may seek outside expert opinions from industry or other sources and make their own recommendations about the process. At times, this results in an adjustment of the LCCA.

It is interesting to note that, although CDOT's Regions operate individually, this Committee provides each with an opportunity to connect with State and National resources that can enhance the quality of the resulting LCCA.

[11] Ibid, pp. 10-82.

WHAT HAS COLORADO LEARNED?

In the 30 years that CDOT has implemented Life-Cycle Cost Analysis, the agency has gained valuable insight into both the use of technology and the importance of human skills in the LCCA process. Among the lessons CDOT wishes to share with other States are:

- A vocal advocate within the leadership of the organization is useful to champion a clear vision and facilitate the process.
- Involving contractor representatives from relevant industries helps clarify issues and promotes buy-in.
- Including other transportation-related offices in LCCA training sessions deepens the use of this practice across the organization. (For example, CDOT middle management is analyzing how pavement LCCA may be applied to selection of culvert types.)
- Since CDOT uses LCCA to determine pavement type, and that affects construction cost, LCCA gives the agency some control over escalating costs because it creates an examination of competing options. The unit cost of material seems to be higher in areas where only one type of pavement has historically been used.
- Pavement performance is better predicted by data from the pavement management system than from subjective surveys.

In general terms, CDOT has found that the use of LCCA allows the agency to better accomplish its mission and serve the public more effectively. CDOT has demonstrated that the use of LCCA can be cost effective. As a result, the State's transportation officials hope other CDOT offices will also be encouraged to adopt LCCA methods.

In implementing and institutionalizing LCCA, CDOT has taken advantage of a number of available State and Federal resources. In particular, it has participated in training offered by FHWA's Office of Asset Management on a variety of topics including pavement management and the use of both deterministic and probabilistic methods of LCCA analysis. [See Figure 2, FHWA Training Related to Pavement Management.]

WAS IT WORTH IT?

In Colorado's experience, the use of LCCA creates positive results within the organization itself and within its larger constituency. For CDOT, the effective use of LCCA:

- Leads to greater communication between the agency and industry representatives, as well as increased dialogue between construction, design, and materials personnel, all of which improves efficiency and roadway performance,
- Keeps engineers current with regard to progressive developments within industry and in costing,
- Provides cost justification to key stakeholders, including highway users, the end customers,
- Helps extend the use of funds by setting priorities during budget shortfalls,
- Creates a two-way feedback loop,
- Aids credibility with roadway users by creating transparency about the agency's decision process, and
- Protects the State.

Photo courtesy of Denis Donnelly, Colorado Asphalt Paving Association

Paving near 10,000' elevation on US 550 at Molas Divide near Silverton.

WHAT'S NEXT?

As CDOT continues to seek progressive ways to provide the most effective multi-modal transportation system for its customers, the agency will increase its emphasis on probabilistic inputs in its LCCA process.

CDOT will incorporate the Mechanistic Empirical Pavement Design Guide (MEPDG) into design practices as soon as it is validated and calibrated to Colorado's site conditions, materials, and typical design features.[12] The agency will continue partnering with FHWA to further improve RealCost software as well. In addition, CDOT hopes to enlist an independent review of its LCCA processes that will identify specific cost savings and opportunities for quality improvement.

CDOT's pavement design and management team will continue to lead the agency in LCCA. The team believes that effective LCCA, when viewed as an investment strategy, will allow the entire organization to make the best, long-range, long-term decisions for the State, especially as it navigates through challenging economic times.

Aerial photo of the South side of Berthoud Pass.

[12] Expected completion date: June 2011.

Concrete paving on I-25 at University Boulevard in Denver.

Aerial photo of I-70 near Shrine Pass.

Additional information is available from the following:

Colorado Department of Transportation. 2009 Pavement Design Manual.

Colorado Department of Transportation. Report No. CDOT-2009-2. Colorado Department of Transportation's Current Procedure for Life Cycle Cost Analysis and Discount Rate Calculations. January 2009.

Colorado Department of Transportation. Report No. CDOT-2006-17. Life Cycle Cost Analysis and Discount Rate on Pavements for The Colorado Department of Transportation. October 2006.

Colorado Department of Transportation. Report No. CDOT-DTD-R-2006-3. Life Cycle Costing. February 2006.

Colorado Department of Transportation. Report No. CDOT-R1-R-00-3. Life Cycle Cost Analysis: State of the Practice. March 2000.

FHWA-IF-03-032. Economic Analysis Primer.

FHWA-IF-03-O38. Transportation Asset Management Case Studies. Life-Cycle Cost Analysis: The Pennsylvania Experience.

FHWA- IF-07-009. Transportation Asset Management Case Studies. Life-Cycle Cost Analysis: The Georgia Experience.

FHWA Life-Cycle Cost Analysis Workshop Powerpoint Presentations. Modules 1 and 2.

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